The HumanoidLab
Involving Students in a Research Centre Through an Educational Initiative

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Abstract: The HumanoidLab is a more than 5 year old activity aimed to use educational robots to approach students to our Research Centre. Different commercial educative humanoid platforms have been used to introduce students to different aspects of robotics using projects and offering guidance and assistance. About 40 students have performed small mechanics, electronics or programming projects that are used to improve the robots by adding features. Robotics competitions are used as a motivation tool. A two weeks course was started that has received 80 undergraduate students, and more than 100 secondary school students in a short version. The experience has been very positive for students and for the institution: some of these students have performed their scholar projects and research in robotics and continue enrolled in the robotics field, and some of them are currently in research groups at IRI.

1 INTRODUCTION

The Institut de Robòtica i Informàtica Industrial (IRI) is a joint research centre between Spanish Research Council (CSIC) and Universitat Politècnica de Catalunya (UPC). In 2007, a SWOT analysis revealed that there was a lack of capacity to involve new students, principally undergraduate and Master students. IRI is located into one of the UPC university campus, but it was relatively unconnected from university activities and the visibility of IRI research areas in the university was very small.

With this in mind, in 2007 the HumanoidLab initiative was created with these objectives:

- Introduce engineering, compute science, and mathematics students to robotics.
- Promote multidisciplinarity in students' education.
- Increase the number of students in the IRI Robotics Laboratory.
- Increase the visibility of IRI research activities in the university community.
- Contribute to the community with open software and hardware projects.

Undergraduate educational robotics can be divided in three areas: robotic clubs, formal university courses, and collaboration into a research project. The HumanoidLab initiative combines a bit all three.

In the first place, some Universities and Research institutions host robotic clubs grouped under different initiatives, like student sections of the IEEE Aerospace and Electronic Systems Society (AESS) [1] or the Board of European Students of Technology (BEST) [2]. These clubs are maintained by students and usually base their activity in organize or participate at national or international robotic competitions, like Eurobot [3] (that takes place from 1998). This competitions propose a set of challenges, and each team designs and builds custom robots with different mechanic, electronic and software solutions. The HumanoidLab wanted to use competitions as motivation tool, but not as primary objective.

In the second place, regular robotic courses involving engineering topics are common (Matari, 2004; Rus, 2006), where simple robots are assembled and programmed with basic reactive algorithms. A good idea to focus the efforts in software development is to use standard and non-expensive robot platforms. In this line, undergraduate experiences using LEGO and AIBO have been reported (Sklar et al., 2007),

[1]http://ieee-aess.org/
[2]http://www.best.eu.org/
[3]http://www.eurobot.org/

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and more recently using Roomba based robots like the TurtleBot (Gerkey and Conley, 2011). However, in these platforms is sometimes difficult to embed more sophisticated computer science topics that underlie perception, planning, and control mechanisms in modern robots (Touretzky, 2012). We liked the idea of using robot kits because they provide a quick start platform for people interested principally in programming, but we also wanted to keep the freedom to customize and replace mechanical and electronic parts, and embedded software.

In the third place, there are lots of students collaborating on scientific projects at university departments, but this is usually not performed as a formal educational activity further than master theses and undergraduate works. Besides, departments and research groups have the capacity to participate in competitions that require complex and expensive equipment. Maxwell (Maxwell and Meeden, 2000) reported an intensive summer project where 10 undergraduate students should collaborate to develop a complex robot used to serve hors d'oeuvres in a sophisticated manner. The RoboCup competitions [4], founded in 1997, promote teams involving students not only on the classical soccer competition but more recently the rescue leagues (from 2001) and in the robocup@home (from 2006). On 2010 it engaged more that 3000 participants from 500 different teams. We considered these activities interesting because they are long term projects where hardware and software platforms are evolved during different years and where collaboration and code reuse is promoted. We also wanted that the students could have the opportunity of develop their Master thesis, undergraduate projects, and collaboration grants under the HumanoidLab.

In this paper, the HumanoidLab initiative is described and the results of 5 years of activity are evaluated.

2 METHODOLOGY

The HumanoidLab group decided to use small humanoid robots in all the activities. Time has revealed that this was a key decision because provided us with a distinctive position. In our area of influence, there was a moderate activity in university and bachelor degrees using wheeled robots, but we were the first using humanoids. Humanoids were (and are) a growing topic in the robotics community and give the opportunity to work both in software and hardware and do

(a) Original Robonova robot (b) Twiki robot

Figure 1: Twiki robot includes many modifications developed as student projects, as additional d.o.f. at legs, pan-tilt unit, foot pressure sensors, color camera, Gumstix processing unit, improved battery system, and a new C programming library.

it in a wide range of different areas: mechanics, electronics, perception, locomotion, kinematics, manipulation, etc. International market offers the possibility to get a fully working educational small humanoid by a reasonable price (800Eur) and consequently with a reduced funding the HumanoidLab could start their activities. Most of the activities use these educational humanoid robots as a base, and foster their capabilities by adding new features.

The project has 4 project administrators, each one specialized in a different area: mechanics, electronics, low level programming, and perception and planning. Each administrator is the responsible for an activity and for different groups of students. As robotics is multidisciplinar, the tight collaboration between different administrators is usually required and is actively promoted in the group. The HumanoidLab is developing 5 different kinds of activities that are detailed below.

2.1 Small Projects

This is the main activity. It involves a small group of students, between 2 and 3, and it is performed during the scholar University period. We organize meetings between students and some of the administrators to determine the previous knowledge of the students, the topic that they would like to work with, and the time that they could spent. Project administrators propose small projects that fit in the current HumanoidLab interests, and students can also propose their own projects. Once an agreement about the project scope and the execution time has been reached, the project starts with the supervision of one administrator. Each new project provides new capabilities to incrementally obtain more complex and capable robots. In section 3 a detailed list of some of the carried out projects is presented.

[4]http://www.robocup.org/

2.2 Competitions

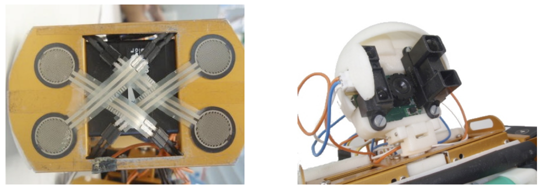
Competitions are not a goal by itself, but an opportunity to put in practice and show the progress of some projects. The HumanoidLab regularly presents some student teams that after the competition write a report (Pons et al., 2010). As it is not a central goal, can happen that the proposed solutions are not the best suited to win the competition, but serve to demonstrate new developments. A clear example is the Twiki robot, who participated at the 2009 CEABOT competition. In the stairs challenge, where stairs have to be recognized and traversed up and down, Twiki used embedded computer vision for obstacle avoidance and pressure sensors to detect downstairs (Pegueroles and Simo-Serra, 2010) (see Fig. 1(b) and 2(a)), while other competitors used simple and effective infra-red sensors. However, it was recognized there as the most technological evolved robot and get the second prize.

In the Spanish national scope, small humanoids competitions are mostly reduced to one or two tournaments per year with events distributed on several days. Each small humanoids contest is composed by several challenges, which can be group into two main categories, depending on what is especially required to the robot:

- Mechanical skills: events designed to probe the robot mechanic design and actuators. An example of this kind its the stairs competition or the sumo contest.
- Perception abilities: events oriented to resolve problems using mainly the robot sensor capacity on the environment. Obstacle race is a good example of this category.

2.3 Introduction Course

UPC University offers the possibility to include a workshop or activity as part of its studies plan. Getting directly into the University studies and participate as an active member has been a good opportunity to have contact with students. A two weeks introductory course/workshop was designed, presented and finally approved by the University. That was the birth of "Introduction to Humanoid Robotics" course. Practice paid a role as important as theory. Participation of students from different schools was one of the strongest proposal points so multidisciplinary teams could be composed. The kind of robots used to perform the practical assignments has evolved from the beginning, and currently from 8 to 10 customized Bioloid robots are used. A maximum of 2 students for each available robot that we have is allowed to join this course at each edition. The course takes 4 hours by day, that is a total amount of 40 hours per course. Past students came from Computer Science, Mechanical Engineering, Electronics, Mathematics and Physics areas.



(a) (b)

Figure 2: Pressure sensors and pan-and-tilt unit on a Robonova robot.

After the great success of this activity we have been asked to propose a shorter introduction activity, of about 2 hours of duration. We have used this shorter activity as outreach in local conferences, secondary school visits, and the European robotics week activities. We have made an effort to develop libraries and tools to facilitate the access to this technology to all kinds of students. Nowadays, the requirements to participate in this course are very basic: knowing the concepts of variable, conditional and loop.

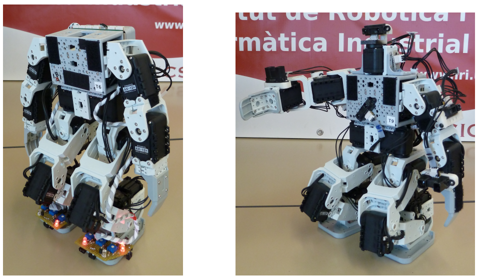
Based on the Introduction course we have also formalized a course in a set of 5 sessions for secondary school teachers, that gives them knowledge and proposes activities to introduce robotics in the secondary school curriculum.

2.4 Curricular Projects

After its participation in some of the HumanoidLab activities, some students decide to perform their curricular projects with us, and sometimes in other robotic groups at the IRI institute. They are basically the final career project (PFC) and the Master Thesis (MTh), but also some undergraduate courses assignments. Some of the works that where performed directly in our group are detailed in Sec. 3.

2.5 Outreach Activities

We have participated in some outreach activities. We have performed some talks at Open Software conferences and to secondary school teachers. we have participated at robot exhibitions like Robot exhibition at Sonar 2010 (Barcelona), IRC 2010 (Korea), and Ficomic (2012). We have appeared on TV and radio programs, and also appeared several times in local newspapers. We regularly participate in the Science Week and in 2012 also in the EU robotics week.



(a) IR foot sensors to detect up and down stairs

(b) Rotating IR sensor at the head

Figure 3: Two different modifications on the Bioloid robot.

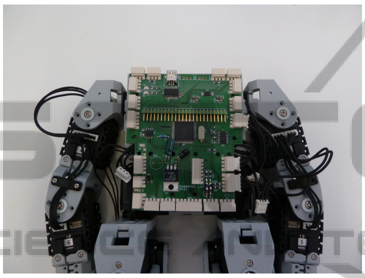


Figure 4: New sensor board for the Bioloid robot.

3 PROPOSED PROJECTS

In five years there have been more that 20 small projects performed. These involve different skills and students have the opportunity to learn different aspects of robotics. A list of some them with code is available on the developers site of the project [5]. Here we list some of the most representative, from the beginning of the project to the latest developments. Along each project it is specified whether it was an students project, a grant, curricular works or coordinators project. We have identified that keeping coordinators motivation is important, and maintain some challenging projects is a good mechanism for such.

3.1 Robonova

The Robonova platform is a 16 dof robot (Fig. 1(a)). It has an embedded micro-controller and can be programmed using a basic-like programming language. It has some analog channels available to use simple sensors.

Inverse Kinematics (students project)**.** This was one of the first activities, defined as a software project. The objective was to define the equations of the Inverse Kinematics (IK) of both arms and legs of the robot, and to implement the corresponding algorithms.
Motivation. IK is important to switch from motions based on pre-computed positions to the complete control over the motion range.
Organization. A group of three students was formed, with complementary knowledge on mathematics an engineering. The project required about 150 hours of work, and 20 hours of supervision based on regular meetings.
Evaluation. Administrators did not correctly evaluated the previous knowledge of the students, and the project required more time than expected. Student were moderately satisfied because they had the opportunity to learn the mathematical background of serial robot kinematics, and the different solutions. One student left the group, and a new project was assigned to the other two in a pure software project following their concerns. An issue was that the project could not be fully completed because the algorithm could not run on the embedded micro-controller. Consequently, the final evaluation was performed in simulation. This motivated the definition of a new electronics project for the addition of a new computing unit.

Extra Dof for Robot Legs (student project)**.** This is a hardware project to modify the leg architecture to allow the inclusion of an extra rotational degree-of-freedom while maintaining almost the same robot height (Fig. 1(b)). This was necessary to not compromise the overall equilibrium.
Motivation. The original Robonova robot has 5 dof at each leg (Fig. 1(a)). Consequently, turns are only possible taking advantage of foot slippage, that is imprecise and with low repeatability.
Organization. The project was assigned to one student with interest in mechanical engineering. The minimum requirements were defined, and the student presented different alternatives that were evaluated, and the best one was implemented on a real robot. The project required about 200 hours of work, and 20 hours of supervision based on regular meetings. The help of the workshop personnel (20 hours) was crucial.
Evaluation. The evaluation was based on the obtained mobility executed by the real robot, and the repeatability of the turning motion. The student found this project as a great opportunity to improve his abilities in mechanical design an related software. He continued in the group, and is now one of the supervisors. The design was published as open source in our website, and several other groups presented similar designs in the next robotics competition.

[5] http://apollo.upc.es/humanoide/

Feet Pressure Sensors (student project)**.** In a previous project a new foot to place force-resistance sensors (FSR) in the bottom and the front, and its associated electronics (Fig 2(a)) was designed. In this project, and thanks to a CSIC grant, a student performed a formal study of the most convenient position and and physical mounting of the sensors, and developed a calibration hardware and software (Barbadillo and Alenyà, 2010).
Motivation. Pressure sensors were used satisfactorily in the skill of climbing up and down stairs. However, we wanted to used them to develop walking algorithms, and more precision was required.
Organization. A single student performed the project. The project was defined taking into account the student background in sensors and electronics. It required 300 hours of dedication. The supervision was based on regular meetings and took 10 hours.
Evaluation. A new evaluation method for us was introduced in this project, based on defining 4 different intermediate checking points with the student. The method worked very well, and let to assess different evolution stages and evaluate the student . It is worth to mention that the knowledge acquired by the student was used in a subsequent research period he performed in another institution (Barbadillo et al., 2011).

3.2 Bioloid

The Bioloid robot is a 18 dof humanoid robot (see Fig. 3) made of modular parts that can be easily changed. Compared to the Robonova, the motors have more torque, and are protected against overload damage. The micro-controller has also basic computation capabilities, and has some analog channels for connecting simple sensors. It come equipped with a small inertial unit intended to aid to the walking motions. The robot is relatively cheap ($\approx$ 800$) so we have 12 of such robots that are used in small projects but also in the Introduction to Humanoids course and related outreaching activities. A project was proposed to add a new extension board (see Fig. 4) to expand the robot controller with different buses and mount new sensors, like a compass. Currently this project has been transferred to a local company that will commercialize it.

Human Motion Transfer (Master thesis)**.** This project uses a depth camera, based on the Time-of-Flight principle, to acquire human motion of an operator and transfer that motions to a Bioloid robot. The student had to implement vision algorithms, 3D segmentation, and implement a communication channel between the vision computer and the robot. Later, with the appearance of Kinect based sensors, the human acquisition part has become more easy, and others have reproduced this work using this sensor (Pfeiffer, 2011).
Motivation. The main objective is to develop a mechanism to create new robot movements that are human-like and easy to create.
Organization. The project was assigned to a student with interest to learn image processing algorithms and interest in control. The project required 400 hours of dedication divided in 3 different stages: 150 hours working in the perception and body segmentation, 50 hours for the adaptation of the IK algorithms and the communication with the robot, 150 hours developing the graphical interface to acquire and reproduce motions, and the rest for writing. It required 35 hours of supervision, and 10 extra hours to solve problems with the image segmentation and robot communication.
Evaluation. This was a Master Thesis project. The student published a report (Siscart, 2011), and the work was publicly presented and evaluated by a jury. The student received the highest qualification. The student was very satisfied because the project entailed closing the perception-decision-control loop, and it had the opportunity to learn perception algorithms.

3.3 Darwin

The Darwin robot (Fig 5) is a 18 dof platform that includes one micro-controller, an embedded PC running Linux, a color camera and an inertial unit. The hardware and the software is open source, and the interaction with the robot is using a C library. Compared to Bioloid, Darwin has a complete PC inside and it is capable of using more complex sensors like color cameras. The architecture is also more robust. However, it costs approximately 10 times the price of a Bioloid. We use this platform for small projects, but it is not possible to have several and use them in the Introduction course. Again, with this platform it is also possible to propose mechanical, electronic, and software projects. For example, in the sensor part a depth camera has been added(Fig 5), and different projects have proposed different solutions to include grippers (Fig 6(a)).

ROS Integration (coordinator project)**.** Currently the ROS framework is widely used and many robots are supported, among others small humanoids. In this project the necessary layers to interface the DarwinOP robot with ROS have been developed.
Motivation. The integration of the robot in the framework enables the use of state-of-the-art algorithms

implementations compatible with ROS, for example for walking (Hornung et al., 2012).

Organization. This project was a coordinator initiative, and assigned to a coordinator because it was a long-term strategical project. It required 200 hours to obtain the first working version. In periodic coordination meetings the evolution was presented and discussed with the other coordinators. The software has been published under LGPL license, following the philosophy of the HumanoidLab. This project is still alive, and requires 5 hours/month of a coordinator for maintenance and to include new features.

Evaluation. The software has been presented in a Darwin competition [6]. Other projects using this software are being proposed, and are used to evaluate and occasionally propose new improvements. The software is also being used by other groups and we receive periodically questions and requirements for improvements that we try to answer.

3.4 Other

Leg Redesign (Master thesis)**.** In this project we investigated how to build a custom pair of legs using powerful motors. The student had to design all the frames and mechanical parts, built the legs, and programmed them to obtain examples of walking gaits. The overall size of the robot was 70cm.

Motivation. Evaluate the complexity and cost of creating custom robot legs to build new robots from scratch.

Organization. The project was assigned to a student with interest in mechanics and hardware abilities. The project required 400 hours of dedication, 30 hours of supervision, and the assistance of the workshop personnel to use the machinery and tools to build the prototype.

Evaluation. This was a Master Thesis project. The student published a report (Cortada, 2010), and the work was publicly presented and evaluated by a jury. He received a high qualification. The evaluation included the demonstration of walking gaits and maximum weight capacity measures.

4 FUNDING

To support the activities of the HumanoidLab we have received different kinds of funding. This has been primarily used to acquire robotic platforms and equipment like computers, additional sensors, and parts, but also to travel to robotic competitions.

[6] http://www.icra2012.org/program/robotChallenge.php

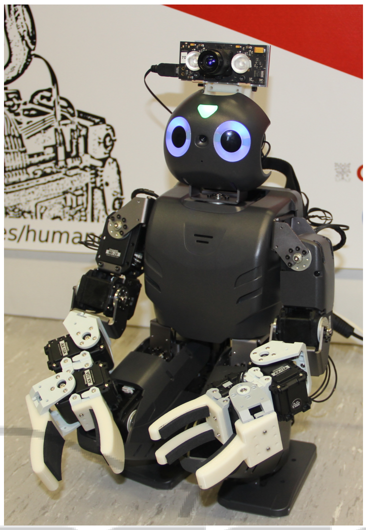
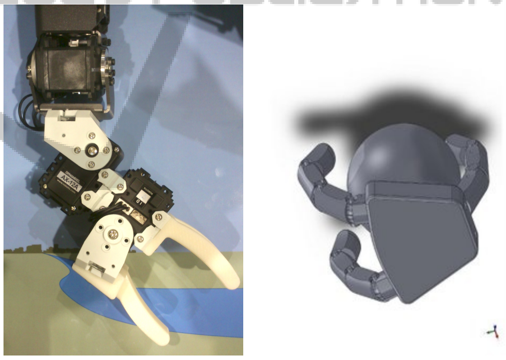


Figure 5: The DarwinOP robot has been modified with grippers and a depth camera. The control system has been completely rewritten to take advantage of the embedded PC/micro-controller architecture.



(a) Simple gripper and additional dof

(b) 3-fingered hand model currently being implemented

Figure 6: Different developments for giving the DarwinOP robot the ability to grasp objects.

Generally students in the lab are volunteers. However, we have obtained funding for grants in three different programs. The first was from the regional government and was intended to foster open source community. We obtained two student grants. The second was from the Spanish Council of Investigation in a program to introduce undergraduate students to research. The third was a program to generate educational contents oriented to secondary school. In total 6 students have obtained a grant.

We started our activities with a reduced number of robots, and we performed some with them small projects and developments. However, this changed when we decided to start the Introduction course and the related outreach activities. More robots were needed to being able to make these activities, as we planned to use one robot for each two students. We obtained the rest of the robots we needed by buying some new units, but also with a donation from a local retailer.

The HumanoidLab has been mainly funded by a program of the Polytechnic University of Catalonia devoted to strength department activities with 20KEur. Currently, the IRI is funding the developments on the DarwinOP platform of the HumanoidLab with an internal project of 15KEur.

5 EVALUATION

The Robotics Introduction Course has had a great success. 80 students have participated in this intensive 2 weeks activity. After each course the opinions of the students are summarized using reviews. Such reviews reveal that before the course the knowledge about IRI activities was 1 in a scale from 1 (unknown) to 7 (totally known) and before was evaluated as 6. The same applies for the knowledge of the HumanoidLab activities. Concerning the evaluation of the course, students declare that will recommend the course to other colleagues between 6 and 7. Of such students, 5 have performed their PFC in the Humanoid Lab and 1 in another group.

The reviews also ask about knowledge acquired in the course. Students consider that the concepts learned will be useful in their career between 5 and 6. The reviews also include specific questions about the concepts divided in 4 sections: (a) kinematics and actuators, (b) sensors, (c) vision, and (d) robot programming. Questions ask for the knowledge before and after the course, and also the satisfaction after the course. Students declare in (a), (b) and (d) a previous knowledge of 1-2, a present knowledge of 5-6, and a satisfaction of 4-5. Surprisingly, regarding (c) previous knowledge is declared the same 1-2, present knowledge is declared low (3-4), but satisfaction is declared high (5-6). We believe that this is because the robots we are using are quite simple, but computer vision are perceived as very powerful tools. Some students have asked, in a free comment space, for a specific activity about computer vision for robotics.

The Introduction course has been served as a basis for creating a course for secondary school teachers, and also a short version is being currently used for outreach activities of the IRI. More than 100 secondary school students have participated in this activity, always in collaboration with their teachers. Students are in general very satisfied, and their teachers have always expressed that the activity has been very positive and helpful.

More than 40 students have been involved in small projects, and contacted the HumanoidLab thanks to word-of-mouth marketing. This has reported a wide list of improvements to our platforms. Some of these new features have been successfully adopted by other groups working with the same robotic platforms.

Women in engineering and robotics are a minority, at least in Spanish education system. Surprisingly, of the 9 active students nowadays in the HumanoidLab 7 are women. We have been asked sometimes for the reasons by researchers in Sociology, but unfortunately we do not have yet the answer.

We have some special cases that is worth to mention. Three former students of the HumanoidLab have performed its PFC in one research group of the IRI, and currently have become PhD students. One of them is still involved with us and has become administrator. Additionally, 3 students have performed their Master thesis in the HumanoidLab.

We have tracks of 3 former students performing research activities related to robotics in research institutions in other countries.

Currently, we have a DarwinOP robot and 12 Bioloid based robots working. Other robots have become obsolete and no further development is performed on them.

Even if it not an objective, participation in competitions has been very successful. The first year our teams obtained the second and the fourth place at the Spanish humanoid competition. The next year we win the second place again, and in the two last competitions the Humanoid Lab team has obtained the first place. These two teams are actually formed by women.

We believe that, for being useful to the objectives of the HumanoidLab initiative, the participation in competitions should be conceived with the following objectives in mind:

- Multidisciplinary collaboration: autonomous contests requires always from both, hardware and software, development. They represent a good motivation to encourage collaboration between groups of students performing different tasks in order to get a robot working or improve them.
- Promote group spirit: since Humanoid Lab hosts several group of students whom compose different teams, some measures were taken to ensure all people feels like belonging to the same organization. It was the tutor mission to explain new teams that all the previous work they were using was made by their co-workers at IRI, but rivals during the competition. It's a golden rule that any prize won by any of the IRI teams is spent on

improving robots and laboratory material. This avoid any problem or ambition with respect to the money and helps a lot on spreading the work results sharing. For competitions which imply displacement to other cities, the own travel and coexistence helps a lot to create bonds among all students, no matter what team they are.

- Provide long and mid-term explicit goals: the resolution of different competitions events can inspire both, tutors and students, in the search of goals to reach. From an specific competition challenge teams can start working on different projects, from mechanical design to artificial intelligence algorithms, in order to be part of tournament competitors.

6 CONCLUSIONS

The HumanoidLab initiative was funded to introduce students to robotics and give visibility to the research activities of IRI in the student community. After 5 years, nearly 100 undergraduate students have participated in one of the organized activities. Of that, 40 have participated in long term activities. Several of them have continued to work in robotics either in IRI or elsewhere. It is worth to mention that 7 of the current 9 students are women.

Using humanoid robots has revealed to be a good decision, because of the distinction with other activities but also because the inherent problems are challenging. Historically different humanoid robots have been used and improved using open hardware and open source paradigms. The set of performed activities include small projects, curricular projects, competitions, courses and outreach activities.

The synergies between mechanical and electronic engineering, computer science, and mathematicians has been very positive and have been explicitly promoted.

Finally, as it is a volunteer activity it is important to keep coordinator's motivation. One suitable way we have found is to propose challenging projects also to the coordinators that allow to learn from other areas or expand their knowledge in new areas. However, it has to be taken into account that long term projects, suitable to be assigned to a coordinator, can require sustained dedication over the time, like software maintenance.

REFERENCES

Barbadillo, G. and Alenyà, G. (2010). Diseño de un pie para un robot humanoide. Technical Report IRI-TR-10-08, Institut de Robòtica i Informàtica Industrial, CSIC-UPC.

Barbadillo, G., Dautenhahn, K., and Wood, L. (2011). Using fsr sensors to provide tactile skin to the humanoid robot kaspar. UH Computer Science 511, University of Hertfordshire.

Cortada, S. C. (2010). Requirements and design of a humanoid robot for playing soccer. Master's thesis, Universitat Politècnica de Catalunya.

Gerkey, B. and Conley, K. (2011). Robot developer kits. *IEEE Robotics and Automation Magazine*, 18(3):16–16.

Hornung, A., Dornbush, A., Likhachev, M., and Bennewitz, M. (2012). Anytime search-based footstep planning with suboptimality bounds. In *Proc. of the IEEE-RAS International Conference on Humanoid Robots*, Osaka, Japan.

Matari, M. J. (2004). Robotics education for all ages. In *Proceedings, AAAI Spring Symposium on Accessible, Hands-on AI and Robotics Education*.

Maxwell, B. A. and Meeden, L. A. (2000). Integrating robotics research with undergraduate education. *IEEE Intelligent Systems*, 15(6):22–27.

Pegueroles, J. and Simo-Serra, E. (2010). Quadern de treball ceabot 2009 - twiki. Technical Report IRI-TR-10-13, Institut de Robòtica i Informàtica Industrial, CSIC-UPC.

Pfeiffer, S. (2011). Guiado gestual de un robot humanoide mediante un sensor "kinect". Master's thesis, Universitat Politècnica de Catalunya.

Pons, S., Tolos, N., and Troyano, S. (2010). Algorismes i modificacions hardware a la robot dorami per participar al campionat nacional de robòtica humanoide ceabot 2010. Technical Report IRI-TR-10-12, Institut de Robòtica i Informàtica Industrial, CSIC-UPC.

Rus, D. (2006). Teaching robotics everywhere. *IEEE Robotics and Automation Magazine*.

Siscart, M. R. (2011). Algorithms and graphic interface design to control and teach a humanoid robot through human imitation. Master's thesis, Universitat Politècnica de Catalunya.

Sklar, E., Parsons, S., and Azhar, M. Q. (2007). Robotics across the curriculum. In *Proceedings of the AAAI*.

Touretzky, D. S. (2012). Seven big ideas in robotics, and how to teach them. In *Proceedings of the 43rd ACM technical symposium on Computer Science Education*, SIGCSE '12, pages 39–44.